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Review & Analysis

Health and Job-Specific Body Composition Standards for the U.S. Air Force

Volume I, Final Report

Prepared for: Force Enhancement Department
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13. ABSTRACT (Maximum 200 Words) The Air Force Medical Service strives to deliver a fit and healthy force, which ultimately translates to sustained and enhanced mission performance. In support of these goals, the Air Force School of Aerospace Medicine's Performance Enhancement Division is pursuing a two-tiered approach to establishing physical fitness programs and standards. Tier I applies health-based standards, while Tier II standards will be (job) performance-based. Specifically, the Air Force is investigating a process to establish body composition standards that are specific to selected job categories. To this end, CSERIAC, the Crew System Ergonomics Information Analysis Center, produced this Review & Analysis which addresses issues regarding the advantages and disadvantages of establishing job-specific body composition standards. The main finding of this Review & Analysis is that the measure of body composition that would best predict military task performance is (total) fat-free mass. Also, the literature suggests that there would be a benefit to establishing job-specific body composition standards. However, the identification of specific cut-points relative to various job categories is a much more convoluted process. The sensitivity and specificity outcomes of any projected body composition metrics may be difficult to derive. Moreover, this approach may have less application for the Air Force compared with the sister Services. Volumes II and III of Health and Job-Specific Body Composition Standards for the US Air Force contain the output from literature database searches. Volume II contains non-copyrighted citations and Volume III contains copyrighted citations. A companion document, Workshop Proceedings – Health and Job-Specific Body Composition Standards for the US Air Force, documents the discussions and consensus among subject-matter experts on these topics.				
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NOTICE

This report contains three volumes. Volume I, this volume, is the final report on issues relevant to the Air Force's consideration of health and job-specific body composition. Volume II contains pertinent non-copyrighted citations extracted from government databases, and Volume III contains pertinent copyrighted citations extracted from commercial databases. A table of contents for the three-volume set may be found in Volume I.

VOLUME I FINAL REPORT TABLE OF CONTENTS

VOLUME I TABLE OF CONTENTS	iii
VOLUME I LIST OF TABLES.....	iv
VOLUME II TABLE OF CONTENTS	v
VOLUME III TABLE OF CONTENTS	v
EXECUTIVE SUMMARY	vi
1. MILITARY FITNESS AND BODY COMPOSITION PROGRAMS	1
1.1 The Air Force Fitness Program	1
1.2 History and Current Status of Department of Defense Body Composition Guidance	1
1.3 The Military Services' Body Composition Programs—Background and Current Status	3
1.3.1 Air Force	3
1.3.1.1 Instruction and Responsibility	3
1.3.1.2 Program	3
1.3.1.3 Standards	4
1.3.2 Army	4
1.3.2.1 Instruction and Responsibility	4
1.3.2.2 Program	4
1.3.2.3 Standards	4
1.3.3 Navy and Marine Corps	5
1.3.3.1 Instruction and Responsibility	5
1.3.3.2 Program	5
1.3.3.3 Standards	5
1.3.4 Coast Guard	5
1.4 Major Body Composition Initiatives	6
2. BODY COMPOSITION: CONCEPTS, MEASUREMENT, AND IMPORTANT FACTORS 8	8
2.1 Concepts and Definitions	8
2.1.1 Body Mass Index	8
2.1.2 Fat-Free Mass.....	8
2.2 Measuring Body Composition.....	9
2.2.1 Hydrostatic Weighing.....	9
2.2.2 Bioelectric Impedance Analysis.....	9
2.2.3 Ultrasound.....	10
2.2.4 Chemical and Computer-Aided Techniques	10
2.2.5 Dual Photon Absorptiometry	10
2.2.5.1 DXA	10
2.2.6 Skinfold and Circumference Measurements	11
2.3 Factors that Affect Body Composition.....	11
2.3.1 Body Composition and Gender Issues	11
2.3.2 Ethnic Differences	12
2.3.3 Body Composition and Age.....	13
3. BODY COMPOSITION AND AIR FORCE FITNESS PROGRAM TIER I: HEALTH, WELLNESS, AND READINESS	14
3.1 Body Composition and Health and Wellness	14
3.1.1 Health.....	14
3.1.2 Injury.....	15
3.2 Body Composition and Readiness.....	15
3.2.1 Fitness	15

3.2.1.1 VO ₂ max Uptake and Running	16
3.2.1.2 Sit-ups and Push-ups	16
3.2.1.3 Other Measures of Strength	17
3.2.2 Military Appearance	17
4. BODY COMPOSITION AND AIR FORCE FITNESS PROGRAM TIER II: JOB-SPECIFIC STANDARDS	19
4.1 History and Current Status of Military Body Composition Standards	19
4.2 What Parameter of Body Composition Should be Used?	20
4.2.1 Fat-Free Mass and Military Tasks	21
4.3 How Can We Establish a Standard?	23
4.3.1 Grouping Air Force Specialty Codes	24
4.3.2 Establishing a Standard for Fat-Free Mass for Each Set of AFSCs	26
4.3.2.1 Predicting Performance on a Military Task from a Test Score	26
4.3.2.2 Predicting ILM Performance from Fat-Free Mass	27
5. SUMMARY/CONCLUSIONS/RECOMMENDATIONS	28
5.1 Summary	28
5.2 Conclusions	28
5.3 Recommendation	28
5.4 Workshop Agenda	28
6. REFERENCES	30
7. APPENDIX A: METHODOLOGY	38
7.1 Search Methodology	38
7.2 Points of Contact/Subject Matter Experts	38
7.3 Organization of Review & Analysis	38

VOLUME I LIST OF TABLES

Table 1. Percent Body Fat Standards for the Military Services	6
Table 2. Components of Services' Body Composition Equations	6
Table 3. Running Performance Correlations with Percent Body Fat	16
Table 4. Subject Matter Experts' Comments on Occupation-Specific Standards	20
Table 5. Correlations among Navy PRT Items and Body Composition Measures with Materials Handling Tasks	22
Table 6. Fat-free Mass is Recommended as a Military Body Composition Parameter	23
Table 7. Air Force Notional Fat Free Mass Requirement	25
Table 8. Military Lifting Categories--Triservice Survey	25
Table 9. Strength Aptitude Codes for AFSC Entry	26

TABLE OF CONTENTS **VOLUME II** **NON-COPYRIGHTED CITATIONS**

TABLE OF CONTENTS	1
Non-Copyrighted Literature Search Introduction	2
1. INTRODUCTION	2
2. DATABASE SEARCHED	3
3. ORDERING DOCUMENTS.....	3
Defense Technical Information Center (DTIC)	3
National Technical Information Service (NTIS)	4
Crew System Ergonomics Information Analysis Center (CSERIAC).....	4
Non-Copyrighted Literature Search	5
DTIC Defense RDT/E On-Line System (DROLS)	5

TABLE OF CONTENTS **VOLUME III** **COPYRIGHTED CITATIONS**

TABLE OF CONTENTS	1
Copyrighted Literature Search Introduction	2
1. INTRODUCTION	2
2. DATABASES SEARCHED	3
3. ORDERING DOCUMENTS.....	3
Defense Technical Information Center (DTIC)	3
National Technical Information Service (NTIS)	4
Crew System Ergonomics Information Analysis Center (CSERIAC).....	4
Copyrighted Literature Search.....	5

EXECUTIVE SUMMARY

Weight limits have been imposed in the United States military services to maintain health and fitness, to reduce injury, and most importantly, to enhance military task performance. The issues addressed in this *Review & Analysis* represent a renewed interest in the importance of body composition, as a result of several recent major government initiatives on the topic.

During the late 1970's, the number of women entering the military increased, precipitating an interest in occupation-related fitness. In 1976, the Government Accounting Office (GAO) recommended that the Department of Defense develop physical fitness standards based on the Department of Labor system of classification, which led to each service defining its critical occupational specialties according to some criterion of upper body strength (GAO, 1976, as cited in IOM, 1998). As a result of legislation in 1993 that permitted women to fill all military specialties that did not involve direct combat, the GAO was asked to re-examine the question of job-specific performance testing. The GAO (GAO, 1996) recommended establishing valid performance standards, providing additional job training, and redesigning tasks. Also focusing on military fitness/body composition standards with an emphasis on gender issues were two investigations by the Government Accounting Office, *Gender Issues—Improved Guidance and Oversight Needed to Ensure Validity and Equity of Fitness Standards*, and *Gender Issues—Information to Assess Servicemembers' Perceptions of Gender Inequity is Incomplete* (GAOa, 1998; GAOb, 1998). The GAO reported on the services' physical fitness programs in November, 1998, and made several recommendations, including ones relevant to the services' body-fat policies and programs. The GAO recommended that there be a clear, DoD-wide, age-based and gender-based body composition standard, and that there be a DoD-wide scientific approach to deriving body-composition standards.

Other drivers behind today's enhanced interest in work-related body composition include a 1994 Defense Advisory Committee on Women in the Services (DACOWITS) conference that noted gaps in research pertaining to health and performance of military women, and a 1995 effort to consider DoD-wide fitness and body composition standards. A Triservice Body Composition effort is currently underway, with the goal of assessing the Committee on Body Composition, Nutrition, and Health of Military Women (BCNH) report.

The Air Force and the Army use body composition standards that take into account age and gender, while the Navy's standards vary for gender but not age. No service uses body composition standards that are specific to job category, although the Department of Defense authorizes the services to establish stricter standards on the basis of specific job requirements or mission needs. The Air Force is considering a process to establish job-specific body composition standards, which is the focus of this report and the subsequent workshop to be held for subject-matter experts.

CSERIAC searched for information on job-specific and health-related body composition standards using technical reports, scientific journals, books, the World Wide Web, and periodicals. Informal conversations with subject-matter experts also provided context, background, and further leads. The workshop that will follow publication of this draft *Review & Analysis* will provide a further forum for subject-matter experts to generate opinion, provide new information, and hopefully achieve consensus on the advisability of establishing job-specific body composition standards.

The following are the major findings of this *Review & Analysis*:

- Many studies have examined the relationship between various measures of body composition and health, fitness, and performance of military tasks. While body fat may be related to health-related fitness and aerobic performance, the measure of body composition that best predicts military task performance is fat-free mass.
- There is some evidence in the literature that leading researchers believe job-specific body composition standards will be of benefit.

- If there is consensus among subject-matter experts at the upcoming *Health and Job-Specific Body Composition Standards Workshop* regarding the utility and feasibility of establishing job-specific body composition standards based on fat-free mass, then two tasks remain:
 - To categorize Air Force Specialty Codes according to lift/strength requirements
 - To quantify the relationship between lift requirements of job categories and fat-free mass

The input of the subject-matter experts at the August, 1999 workshop will be invaluable. The most important issue to be discussed will be the practical utility of establishing body composition standards that are specific to Air Force Specialty Codes. Specifically, the technical knowledge base and experience in the military arena of the subject-matter experts will provide an analysis of these questions:

- Will there be significant savings in job efficiency, military readiness, injury reduction, and staff morale?
- Will these benefits outweigh the costs of the process to establish standards?
- Can the Air Force afford to be more selective rather than less selective in its recruiting and job assignment processes?
- Is the Air Force willing to deal with the effects of disgruntled personnel who do not conform to occupation-specific body composition standards but may otherwise be well qualified for a given assignment?

The Air Force faces a challenging set of issues. Establishing job-specific body composition standards that are valid and reliable is a process that will require leveraging the knowledge base and data resources of all the services and perhaps international agencies as well. Although the methodology to accomplish this task is available and well-documented, decomposing the vast range of military occupations into their component tasks and determining valid estimates of the appropriate body composition measure will be an enormous undertaking.

1. MILITARY FITNESS AND BODY COMPOSITION PROGRAMS

1.1 THE AIR FORCE FITNESS PROGRAM

Military readiness depends on service members who are healthy, fit, and who can perform their tasks safely and efficiently. Service members must adhere to body composition and fitness standards as evidence of their readiness to deploy at a moment's notice. The implications for failure to meet the services' standards are great—both for the defense of the country and the career path of the individual.

The goal of the Air Force Physical Fitness Program is to deliver a fit and healthy force that operates at a high level of mission performance and at a minimal risk for injury and illness. To meet this goal, USAF fitness professionals are continually working to produce a program that is valid, reliable, legally defensible, and practical to administer (Palmer & Soest, 1997). In addition, Air Force efforts must also take into account policies of the Department of Defense and be relevant to the programs of sister services. Key considerations to address are standards development, gender and age differences, and practicality and safety of administration.

In order to deliver a fit and healthy force that enhances mission performance, the USAF Force Enhancement and Fitness Division is pursuing a two-tiered approach to the establishment of programs and standards. The objective of Tier I will be primarily health-based fitness with programs and standards that apply to all Air Force personnel. These standards will be gender-dependent in order to account for the physiological differences between males and females. Individuals must meet these threshold values to signify a health-related level of fitness, above which distinct health benefits will be realized and identified. Conversely, a person whose levels are below these standards carries the increased risk of injury, disease, and decreased readiness.

Tier II of the Air Force Fitness Program focuses on an occupation-specific, performance-based fitness program that will further enhance mission readiness and accomplishment. Performance-based standards are gender-independent with thresholds based on occupational requirements. These thresholds represent each type of physical fitness necessary for individuals to meet the physical requirements of their Air Force Specialty Code (AFSC). Inability to meet these standards implies a reduced level of readiness, an increased risk of mission failure, and an increased risk of injury.

The requirements for Tier I and Tier II will include standards for muscle strength and endurance, cardiovascular fitness, and body composition. Body composition is an important fitness parameter that has implications for health, fitness, and occupational performance (IOM, 1998). Both underweight and overweight conditions are associated with increased health risks and decreased performance. Establishing science-based optimal body composition standards for health and job performance is vital to the military occupational physiology community. Making a determination about the utility and feasibility of establishing body composition standards that are aligned with groupings of AFSCs is one goal of the Air Force Fitness Program, and it is the focus of this *Review & Analysis*.

1.2 HISTORY AND CURRENT STATUS OF DEPARTMENT OF DEFENSE BODY COMPOSITION GUIDANCE

Weight standards have been applied in the military for over one hundred years (Friedl, 1992). All of the services have body fat limits for men and women with retention contingent on meeting those standards. The services vary in their stated goals, which include health considerations, military appearance, physical fitness, and job performance. Regardless of the specific motivation of the services, the simple existence of body composition standards promotes improved physical fitness habits by encouraging better nutrition and regular fitness activity. Body composition standards help to maximize fitness in a unique way, because, compared to other fitness measures, they are more stable, and reflect longer-term health and fitness habits (Friedl, 1992).

DoD guidance published in 1981 and revised in 1995 (US Department of Defense, 1981, 1995) requires that the services set up and maintain physical fitness and body fat programs. The Assistant

Secretary of Defense for Force Management Policy has oversight for these programs and coordinates with the Assistant Secretary of Defense for Health Affairs. DoD program guidance requires that all service members possess the cardiovascular endurance, muscle strength and endurance, and whole-body flexibility necessary to perform their service-specific mission and military specialty. The guidance does not specify the requirements for specific activities or levels of difficulty. Guidance also states that a desirable body composition is an integral part of physical fitness, general health, and military appearance.

Evaluation of military fitness is regulated at the national level by DoD Instruction 1308.3 (US Department of Defense, 1995), which requires the services to use physical fitness tests of cardiovascular and muscular endurance. All service members, regardless of age, must be tested, although test standards may be adjusted for age. Standards may also be adjusted for gender. All service members must be formally tested at least annually, and if the individual does not pass, the test report must include documented comments.

The 1981 body fat standards established by DoD (US Department of Defense, 1981) were based on scientific texts indicating that the average body fat of young men who were physically fit was 20%, and for women, 30%, with a 5% margin of error to allow for deviation from the mean and for measurement error (IOM, 1998). The DoD guidance that was published, however, included the 20% figure for men but lowered the figure for women from 30 to 26%, in the belief that “it was desirable to recruit women whose body fat was closer to that of the average man, as such women, possessing a higher than average proportion of fat free mass, might also be more similar to men in strength and endurance” (GAO, 1998a, p. 18). These standards were in effect until 1995, when DoD instruction cited acceptable body fat levels of between 18 and 26% for men and 26-36% for women. DoD officials had no rationale for the change, although officials interviewed for the GAO report said that the change was based on the desire to cover the “full range of standards in effect in the services at the time and that no scientific research was conducted” (GAO, 1998a, p. 18). The weights indicated in the DoD screening tables for body fat are drawn from Andres, 1985. The weights and percent fat equivalents are slightly greater than those associated with 120% of the midpoint of the medium frame weights.

In addition to these guidelines, the DoD authorizes the services to establish stricter standards on the basis of specific job requirements or mission needs. The DoD also requires that test standards be adjusted for gender-based physiological differences, with an 8 to 10% difference in specific body fat standards. DoD guidance also stipulates that the services may not derive the equations applied to one gender from data gathered from the other gender.

Currently, DoD instructions set body fat control policies requiring all the services to use a two-stage screening process. If the weight parameters for a given person’s height are exceeded using a screening table, or if the immediate commander determines that a servicemember’s appearance suggests excess body fat, then the servicemember’s percent of body fat is to be estimated. Validated circumference equations allow for the best distinction between someone who is overweight due to excess body fat and someone who has greater than normal muscle mass. Some of these assessments include measurements of neck, waist and abdomen for men; hips, waist and neck for women (optional measurements include wrist, abdomen, and/or forearm for women).

Failure to meet the fitness and body fat standards results in a probationary period during which progress must be demonstrated. If progress has not been made in this time, the individual is referred to medical personnel. Fitness standards must be met by service personnel if they are to continue in their chosen professions. Service members can be denied promotions, schooling, and other benefits, and can be forced to leave the military for continued failure to meet these standards.

In summary, the Department of Defense guidance leaves some latitude in how the services will administer body composition programs. The services vary in their height-to-weight standards used to screen personnel and the equations and standards used with circumference measurements. The specifics of the various services’ programs are described in the next section.

1.3 THE MILITARY SERVICES' BODY COMPOSITION PROGRAMS—BACKGROUND AND CURRENT STATUS

Each branch of the military services has its own individual fitness history and standards. All the services use a height-weight table as a screening device. Personnel who do not pass this step are referred on to a circumference measurement procedure that predicts body density, percent body fat, or fat-free mass. The criterion measurement used during development of these equations was body density from underwater measurement or percent body fat using the Siri equation to convert body density to percent body fat.

Some services are more stringent than others, allowing less variability in weight with respect to gender or age. In addition to the differences in the services' weight-for-height standards, there are considerable differences in maximum allowable body fat percentages derived from circumference measurements. GAO reports that these standards seem to "bear little logical relationship to the weight-for-height values that are used as a body composition screening tool" (GAO, 1998a, p.12). The services' maximum allowable body fat percentages range from 18 to 26% for men and 26-36% for women. While the Air Force's circumference standards represent a more stringent body fat requirement, the Air Force's maximum allowable weights are often higher than Army weights for a given height.

1.3.1 Air Force

1.3.1.1 Instruction and Responsibility

The Air Force's Weight Management Program is governed by Air Force Instruction 40-502, *Weight and Body Fat Management Program*. AFI 40-502 governs Air Force Policy Directive 40-5, *Fitness and Weight Management*. The medical and counseling policies of these programs are the responsibility of the Deputy Chief of Staff for Personnel, the Air Force Surgeon General, and the Air Force Nutrition Committee, while the overall responsibility for the administration of the weight management program lies with the Installation Commander (IOM, 1998, p. 89).

1.3.1.2 Program

All personnel are weighed at least once annually without notice and may be instructed to weigh in at other times by the commander or supervisor. If an individual exceeds the weight-for-height standards or fails to present an appropriate level of professional military appearance, the individual must undergo a second assessment procedure, which consists of circumference measurements whose values are applied to predictive body composition equations (Hodgdon & Beckett, 1984a, b).

If the outcomes of the applied equations indicate excessive body fat, then the service member is referred for medical evaluation. If the outcome is negative for an underlying medical condition, the individual enters the first phase of the Weight and Body Fat Management Program, receives diet counseling and participates in a 3-month exercise and dietary period. During this time, enlisted members are ineligible to test for or assume a higher grade or to reenlist, and officers lose their promotion line number and projected promotions are cancelled.

After successfully completing Phase I of the Weight and Body Fat Management Program, individuals are entered into Phase II, a six-month observation period during which personnel are weighed monthly. Also during this phase, all promotion and training privileges are reinstated, but promotions are not retroactive. Those who fail to make satisfactory progress (with progress defined as a decrease of at least 1% of body fat per month or 5 pounds for men and 3 pounds for women) are subject to administrative sanctions, including separation, as documented in Air Force Instruction 40-502.

1.3.1.3 Standards

The background of the Air Force body composition program was derived by authors of the 1998a GAO report via an oral history constructed through discussions with officers who were responsible for the program. Air Force officials were unable to provide studies or records to document their body fat standards. The Air Force once used equations that predicted fat-free mass instead of percent body fat during annual physicals, but now uses body fat estimation equations similar to the Navy's.

The maximum body fat allowable by age and sex follow (AFI-40-502):

- Twenty percent (20%) for men 29 years old and younger
- Twenty-four percent (24%) for men 30 years old and older
- Twenty-eight percent (28%) for women 29 years old and younger
- Thirty-two percent (32%) for women 30 years old and older

1.3.2 Army

1.3.2.1 Instruction and Responsibility

The US Army Deputy Chief of Staff for Personnel oversees the Army Weight Control Program. Counseling and medical policies are under the aegis of the US Army Surgeon General. Commanders and supervisors have responsibility for evaluation of weight, appearance, body fat measurement, and assignment to the weight control program as described in Army Regulation 600-9, entitled, *The Army Weight Control Program* (US Army, 1986).

1.3.2.2 Program

As part of the Physical Fitness Test (PFT), all personnel are weighed every six months. More frequent assessments of weight and body fat are at the discretion of the commander or supervisor (US Department of the Army, 1986). Personnel whose weight-for-height exceeds the table values are referred to body fat evaluation through circumference measurements. Those who exceed body fat standards are referred for medical evaluation. If no underlying problem is detected, the individual is enrolled in the weight management program and must lose according to a goal, of between 3 and 8 pounds per month. If insufficient progress is made for two consecutive months, or after 6 months in the program, there may be additional medical evaluation or separation from the Army.

1.3.2.3 Standards

The Army now allows body fat of up to 20-26% for men and between 30 to 36% for women. The lower figure for males was derived from data on young males soldiers from a decade ago (GAO, 1992); adding 2% body fat for each decade after the second yields the upper figure of 26%. Up until 1991, female standards of 28 to 34% were derived by the addition of 8 percentage points to the male standards. These figures were determined to be more restrictive than the men's when the allowable body fat was compared to the means of same-sex recruits. In 1991, 30 to 36% were established as the lower and upper figures for Army women. The equations used by the Army were developed by Vogel and coworkers (1988), on a population now thought to be not representative of the military population in terms of race and gender (GAO, 1998a).

1.3.3 Navy and Marine Corps

1.3.3.1 Instruction and Responsibility

Naval Operations Instruction 6110.1E (1998), *The Physical Readiness Program*, governs the Navy Weight Loss Program. This program also uses *Navy Nutrition and Weight Control Self-Study Guide: Forge the Future* (HAVPERS 15602A), a study guide that is used by those who exceed fat standards. Commanding officers provide the overall program that includes nutrition education, and the program is administered by fitness counselors.

1.3.3.2 Program

Navy personnel are weighed every six months as part of their Physical Readiness Test. Individuals who exceed the weight-for-height standards undergo circumference measurement and those whose body fat exceeds the standard are referred for counseling and rehabilitation.

Level I is a six-month remedial physical conditioning program that may include nutrition education. Failure to progress in this level results in a 2 to 6 week intense outpatient weight management counseling program, Level II. Level III was eliminated in 1995, and was an inpatient obesity treatment program that lasted for 4 to 6 weeks. In 1996, 2-week outpatient lifestyle and nutrition education was enacted.

1.3.3.3 Standards

The Navy's standards are not age-specific. The 1985 NIH definition of obesity has been used as an upper limit for males, with a conversion of the 1983 Metropolitan Life weight-for-height values into mean body fat percentages of 22% for males and 33% for females. These figures were recommended as Navy maximums for body fat (NIH, 1985). The recommendation for men was accepted, but command concerns about appearance dropped the female standard to 30%. In 1998, the female standard was unexpectedly raised back to the originally recommended 33%. The Navy's equations were developed by Hodgdon and Beckett (1984a, b) at the Naval Health Research Center.

The Marine Corps had no available documentation on the development of male or female body fat standards. The GAO's interview with Marine Corps officials revealed that the standards were based on command judgments regarding fitness and appearance, as opposed to actuarial tables or any other scientific basis. Some limited research may have been applied, however, since regulation defined the maximum allowable body fat percentage for males as 18%, which is just below the midpoint of the interval between the 10% figure said to be the average for marathon runners and the 30% figure that defines gross obesity. The female standard of 26% is at about the 80% point of the interval between the 11% body fat level which the regulation says is that of the average female gymnast and the 30% level which defines gross obesity in women. The Marine Corps now uses a circumference equation that was developed at the Naval Health Research Center by Hodgdon, which takes into account neck and abdomen measurements for men and neck, waist, and hips for women. It is based on a four-component body composition criterion. A recent study by Graham, Hourani, Sorenson, and Yuan (1999) showed that between 20% and 30% of Navy and Marine Corps personnel exceeded weight-for-height standards, with women meeting standards slightly more often than men.

1.3.4 Coast Guard

Coast Guard standards range from 23 to 27% for men and from 33 to 37% for women, depending on the age of the individual, from under 30 to over 40. Testing is performed annually and upon random urinalysis testing.

Table 1 describes the percent body fat standards for the Air Force, Army, Navy, Marines and Coast Guard, and Table 2 describes the components of the body composition prediction equations used by each of the services.

Table 1. Percent Body Fat Standards for the Military Services

	Men		Women	
	Age (Years)	% Body Fat	Age (Years)	% Body Fat
Air Force	<29	20	<29	28
	30+	24	30+	32
Army	17-20	20	17-20	30
	21-27	22	21-27	32
	28-39	24	28-39	34
	40+	26	40+	36
Navy	All	22	All	33
Marine Corps	All	18	All	26
Coast Guard	<30	23	<30	33
	31-39	25	31-39	35
	40+	27	40+	37

Table 2. Components of Services' Body Composition Equations

	Men	Women
Air Force	Abdomen Neck	Abdomen Hip Neck
Army	Abdomen Neck	Wrist Neck Forearm Hip
Navy	Abdomen Neck	Abdomen Hip Neck
Marine Corps	Abdomen Neck	Neck Waist Hips

1.4 MAJOR BODY COMPOSITION INITIATIVES

So far this *Review & Analysis* has described overall DoD guidance on body composition, as well as the specifics of the major services' programs. This section discusses the motivation behind the services' considerations for body composition program change. The drivers include gender considerations, due to the increase of women in the armed forces, as well as legal issues, and advances in science, all of which are addressed in several major government initiatives that have investigated military body composition issues in the past decade. The documents describing these programs are very relevant to the questions being raised by the Air Force's Force Enhancement Fitness Division. The first such publication, *Body Composition and Physical Performance*, was written by the Committee on Military Nutrition Research (CMNR) of the Institute of Medicine. The CMNR was tasked by the US Army with the evaluation of body

composition and fitness standards for recruitment and retention in the military services, publishing their findings in 1992.

Further investigation of the question of job-specific performance testing was motivated by 1993 legislation permitting women in all MOSs that did not involve direct combat. GAO (GAO, 1996) conclusions included establishing valid performance standards, increasing job training, and redesigning tasks.

Following a 1994 Defense Advisory Committee on Women in the Services (DACOWITS) conference, the Institute of Medicine (IOM) of the National Academy of Sciences released a report noting gaps in research pertaining to health and performance of military women. Also, in 1995 there was an effort to consider DoD-wide fitness and body composition standards, which led to the CMNR being asked to create a subcommittee to address issues of body composition, fitness, appearance standards and their impact on the health, performance, and nutritional status of military women. The findings of this Committee on Body Composition, Nutrition, and Health of Military Women (BCNH) appear in the IOM document, *Assessing Readiness in Military Women* (1998). A Triservice Body Composition effort is currently underway, with the goal of evaluating the recommendations of the BCNH report, and recommendations are due by the end of 1999.

Also focusing on military fitness/body composition standards with an emphasis on gender issues were two investigations by the Government Accounting Office, *Gender Issues—Improved Guidance and Oversight Needed to Ensure Validity and Equity of Fitness Standards*, and *Gender Issues—Information to Assess Servicemembers' Perceptions of Gender Inequity is Incomplete*. The Government Accounting Office (GAO) reported on the services' physical fitness programs in November, 1998, and made several recommendations, including ones relevant to the services' body-fat policies and programs. The GAO recommended that there be a clear, DoD-wide, age-based and gender-based body fat standard, and that there be a scientific DoD-wide approach to deriving body-fat standards.

2. BODY COMPOSITION: CONCEPTS, MEASUREMENT, AND IMPORTANT FACTORS

2.1 CONCEPTS AND DEFINITIONS

The science of anthropometry defines reliable physical measures of a person's size and form for anthropological comparison (Chaffin & Anderson, 1991). Occupational physiologists have used measures of body parameters, including height, reach, range of motion, and strength in employee selection and job assessment, in an effort to improve productivity and reduce the rate and severity of injury. For instance, in the Air Force arena, there are height standards for pilots and strength standards for AFSCs.

Evaluation of body composition is an important variable in many contexts, including medicine, health-related fitness, occupational medicine, and performance athletics. This section reviews some of the important concepts and measurement techniques used in assessment of body composition.

Body composition analysis is concerned with measuring sub-divisions of the body, which can be split into two, three, or even five compartments (Pollock, Garzarrella, & Graves, 1995). Typically, the two compartment model is used with hydrostatic weighing. This model consists of fat and fat-free body mass. Fat is that part of the body that consists of all extractable lipids (Stolarczyk & Heyward, 1998), while water, protein, and minerals with no lipids compose the fat-free compartment of the body (Siri, 1961, Lohman, 1992). The two-component model assumes relative density values of fat and fat-free components, assumes that these values remain constant, and assumes that individuals differ from the reference body only in the amount of fat (Stolarczyk & Heyward, 1998). Two-component equations (such as that of Siri, 1961) convert total body density from hydrostatic weighing to percent body fat. While some errors exist in this method, they can be accurately estimated (Lohman, 1991).

2.1.1 Body Mass Index

A common measure of body composition is the body mass index (BMI), defined as weight in kilograms divided by the square of height in meters and can vary between 14 kg/m² to greater than 100 kg/m² (IOM, 1998). Most federal agencies consider a BMI between 18 to 28 kg/m² as "healthy," according to the Institute of Medicine (IOM, 1998), although several recent studies support a BMI range of 19 kg/m² to 25 kg/m² (USDA/DHHS, 1995; Manson et al., 1995). There is some debate about the desirable range, as health risks have been shown in some studies not to increase significantly until about 27 kg/m² (Kannel, D'Augustino, & Cobb, 1996; Troiano, Frongillo, Sobal, & Levitsky, 1996). While BMI provides valuable information, Welham and Behnke (1942) showed that increased weight for a given height may indicate greater than average bone or muscle mass rather than excess body fat. This realization led to the derivation of more finely-tuned assessments of body composition so that for individuals whose BMI is above average, it could be determined if they possessed greater than average muscle mass or were simply overfat.

2.1.2 Fat-Free Mass

In the simplest two-component model, fat-free mass (FFM) is the difference between total body weight and fat mass, taking into account water, skeletal muscle, bone, and visceral organs, with skeletal muscle constituting about one-half of FFM (Wang et al., 1996). FFM is the component most often associated with strength and endurance. It has thus been considered an estimate of skeletal muscle mass, similar to adipose-tissue-free mass measure. However, new imaging techniques such as whole-body multi-slice magnetic resonance imaging (Heymsfield, Ross, Wang, & Frager, 1997), and dual-energy x-ray absorptiometry, open up even more precise muscle mass prediction models. These new techniques also offer better estimates of bone mineral mass and density.

2.2 MEASURING BODY COMPOSITION

There are numerous ways to assess body composition, that is, the makeup of the body at the molecular and anatomical levels (IOM, 1998). Body composition assessment can be through direct measurement or indirect estimates. Direct measurements are made using chemical analysis while indirect methods are based on less specific assessment (for example, circumference, skinfold thickness, densitometry/ hydrostatic weighing, or bioelectric impedance), whose results are used in calibrated equations to yield measures of body composition. The monograph by Behnke and Wilmore (1974) provides a thorough analysis of anthropometry, desitometry, caliper-measured skinfolds, and radiogrammetry for establishing body composition. More recent advances in indirect measurement have led to potassium 40 counting, total body water from tritium or deuterium dilution, and total body carbon from neutron activation (Chumlea & Baumgartner, 1992). Indirect methods will result in some error of prediction (2.5 % for densitometry to 3-9% for anthropometry).

Guo and Chumlea (1996) state that “the sophisticated ‘direct’ methods for the measurement of body composition are time-consuming, expensive, and require fixed dedicated equipment and support in a laboratory setting. In epidemiological and clinical settings, it is frequently necessary to predict body composition (for groups or individuals) because the application of sophisticated direct methods is not practical” (p. 191).

2.2.1 Hydrostatic Weighing

Hydrostatic weighing, densitometry, or underwater weighing has been considered the gold standard by which all other measurement techniques are compared (Lohman, 1984; Roche, 1987). This indirect method assumes a two-compartment model, that is, that the body can be divided into two compartments, fat free (lipid free) and fat. A participant is weighed in the air and then in water, requiring up to 10 repetitions to achieve accurate results. Since muscle and bone are more dense than fat, the weight difference between fat and fat free mass can be calculated using equations based on the two-compartment model. For instance, fat is assumed to have a density of 0.9 g/cc, while various fat free structures have greater densities (muscle = 1.01 g/cc, bone = 1.11 g/cc) (Pollock, Garzarella, & Graves, 1995). However, neither of the dual compartments remain constant. Age, ethnic background, muscle tone, and even gender have an impact on the various densities, and thus, the measurement (Grinker, 1992).

2.2.2 Bioelectric Impedance Analysis

Widely used in a variety of settings, such as hospitals, clinicians’ offices, and health clubs, bioelectric impedance is simple and quick to use, and is not invasive (NIH, 1994). Bioelectric impedance analysis (BIA) measures the bodily tissues’ opposition to the flow of a mild alternating electrical current. This method is based on the principle that the resistance of a low level current is inversely related to the amount of fat free mass (FFM) in the body, since fatty tissue does not conduct electricity as well as lean tissue. By placing electrodes on the arms and legs and passing a low-level current through the body, resistance can be measured and applied to a formula that yields the FFM and percent body fat (IOM, 1992). The NIH Technology Assessment Conference Statement (NIH, 1994) indicates that,

“BIA values are affected by numerous variables including body position, hydration status, consumption of food and beverages, ambient air and skin temperature, recent physical activity, and conductance of the examining table. Reliable BIA requires standardization and control of these variables. The panel concluded that there was not adequate consensus information to define a single, specific procedure for conducting routine BIA measurements. Therefore we recommend that a committee of appropriate scientific experts and instrument manufacturers

be formed with the goal of setting instrument standards and procedural methods.” (p. 12)

2.2.3 Ultrasound

Another indirect technique of body composition measurement is ultrasound. Based on a theory by Cromwell, Weibell, and Pfeiffer (1980) and functioning much like a radar, ultrasound sends supra-audible frequencies (above 20kHz) out from a source or probe, which are reflected back. These reflections give information on density and depth of underlying structures, specifically where there are medium changes or intersections between structures (e.g., skin-fat, fat-muscle, and muscle-bone interchanges). There are two modes of ultrasound, A and B. The older A mode has difficulty providing a coherent picture of which echos are produced by which structure. The newer B mode overcomes this, providing a printable picture of underlying structures. Although ultrasound requires somewhat expensive equipment and considerable training to operate, it has been shown to be accurate and reliable with correlations of over 0.97 as compared to direct needle puncture and bioelectric impedance methods (Bullen, Quaade, Oleson, & Lund, 1965; Booth, Goddard & Patton, 1966), making it an effective method of measuring body composition. Roche (1996) states that B-mode ultrasound and caliper measurements of subcutaneous adipose tissue are about equal in precision, and that ultrasound provides the benefit of a hard copy and little or no compression, although this latter issue may be less important than has generally been considered.

2.2.4 Chemical and Computer-Aided Techniques

There are several more direct techniques that, while extremely accurate, are not practical to use on large populations of humans. Some are impractical because they require the subject to either digest a potentially hazardous chemical or are used on a cadaver. These methods include potassium 40 counting, total body water measurement from tritium or deuterium dilution and total body carbon from neutron activation (Chumlea & Baumgartner, 1992). Another measurement technique that is too costly for broad use is computer-aided measurement, specifically computerized tomography (CT), which involves radiation exposure, and magnetic resonance imaging (MRI). Both require very expensive equipment, costing in the millions of dollars, and highly trained technicians, while providing little additional precision or accuracy when compared to newer techniques (IOM, 1998).

2.2.5 Dual Photon Absorptiometry

Dual photon absorptiometry (DPA) is the newest development in direct body composition measurement. Highly convenient, these techniques give information about total body mineral and skeletal mass, as well as total body density. While they do expose the subject to more radiation than CTs or MRIs, the exposure is minimal, allowing for repeated measures to be taken safely. DPA has been shown to be rather accurate during validation studies, with correlations of 0.92 to 0.95 (SEEs 3.2% and 2.5%, respectively) according to Lohman (1992). There are several types of DPA, but the newest is dual energy projection analysis.

2.2.5.1 DXA

A recent development in DPA is dual-energy X-ray absorptiometry (DXA), also known as DEXA, DRA, QDR, DER, and DEPR (Lohman, 1996). A noninvasive radiologic projection technique, it uses minimum exposure to low levels of X-rays. Using enhanced resolution, DXA instruments can differentiate body weight into three chemical compartments—lean soft tissue, fat soft tissue, and bone (Heymsfield & Waki, 1991) and have the ability to distinguish regional and whole-body parameters of body composition. Tissue densities are directly measured and differentiated, giving it a decided advantage over all indirect measurement methods, especially anthropometric and the highly regarded hydrostatic methods. Using

information provided by DXA, newer and better equations are being developed for indirect methods of body composition analysis. In addition, DXA requires less equipment and fewer trials than hydrostatic methods. Lohman (1996) states that DXA offers a precise estimation of several aspects of body composition, and is better at total body composition assessment than regional estimates, although large subjects may yield inaccurate body fat assessments with DXA. The major downside to DXA is the cost, with each unit costing up to or exceeding \$60,000 (Pollock et al., 1995). Given the speed and accuracy of DXA, in spite of the cost, it appears to be moving to the forefront of body composition measurement (IOM, 1998).

2.2.6 Skinfold and Circumference Measurements

Anthropometric techniques are indirect methods of measurement that utilize various body dimensions and girths applied to specific equations. The most common measures are height, weight, body circumferences/diameters, and skinfold thicknesses (Behnke & Wilmore, 1974). These used methods of assessing body composition are characterized by ease of application, simplicity, low cost, and relatively good correspondence to other techniques (Pollock et al., 1995).

The draft Air Force Instruction 40-502 states, “The circumferential measurement technique (tape measurement) is the only acceptable method authorized by DoD for determining body fat percentage” (p. 1). At this time, all US military services use equations based on circumference measurements to derive their body composition standards. Hydrostatic weighing, calipers, or infrared measurements are not authorized measurement techniques. The body circumference technique consists of measuring the girth of various parts of the body, including the neck, chest, waist, upper and lower arms, thigh, calf, and hips. Well-trained technicians can generate circumference measurements with low error and high reliability (Norton & Olds, 1996).

Determining skinfold thickness requires a technician to measure an individual at various points of the body using skinfold calipers, which basically measures a pinched fold in the skin, yielding a precise thickness measurement and the amount of interposed fat beneath. Important locations of measurement include biceps, triceps, subscapular, suprailiac, abdomen, thigh, and medial calf (Grinker, 1992). Both the circumferences and the thicknesses are then entered into precise equations to determine body composition. Measuring skinfold dimensions is considered noninvasive and simple to perform, but is not as accurate as circumference measurements. Lukaski (1992) notes that this technique makes the unvalidated assumption that subcutaneous adipose tissue reflects a constant proportion of total body adipose tissue, and also assumes that the sites selected for measurement represent the average thickness of adipose tissue.

Body fat estimated from circumference measurements have been shown to be equally or more accurate than BIA and skinfold measurement (Kujawa & Hodgdon, 1998). Reliability for skinfold thicknesses is somewhat problematic as determined by Katch and McArdle (1973). After 150 skinfold measurements, technicians showed only a 24% proficiency while the same technicians showed 68% accuracy with only 45 circumference trials. Difficulties in using anthropometric techniques to accurately assess fatness in women with regional adiposity are described in Swan and McConnell (1999).

2.3 FACTORS THAT AFFECT BODY COMPOSITION

While many of the relationships between components of the body are stable, individual differences also affect these relationships. Some of the variation is attributable to age, gender, and ethnicity, and these factors are important ones to be considered in the military’s establishment of health-related body composition standards.

2.3.1 Body Composition and Gender Issues

Although there is overlap between the body composition distributions of the sexes, for the most part men are longer and heavier than women, and possess a larger lean body weight (Garn, 1992). Women

have a higher percentage of body fat, on the average, than do men (Frisancho, 1984). Garn, (1992) however, points out that while women generally have a thicker panniculus of outer fat, this is not always the case.

A minimum amount of fat, called essential fat, is required for metabolic needs and to protect body organs and cell structure (Sharp, 1994); this amount is about 12% of body weight for women, and only 3% of body weight for men (McArdle, Katch, & Katch, 1991). Women store this additional essential fat in the breasts and around the reproductive organs (McArdle, Katch & Katch, 1991). Fitzgerald, Vogel, Daniels, et al.(1986) and Vogel (1992) report that, compared to the average male soldier, the average female soldier weighs 20% less, has 10% more body fat, and has 30% less muscle mass.

There have been complaints that the services' body composition standards are unfair, unrealistically biased, and selectively enforced, sometimes to the detriment of women (GAO, 1998b). Another GAO report (1998a) found that the services' body composition standards were not always derived from scientific data, that the various equations used by the services result in widely varying estimates of body fat for the same person, and that the populations used to derive these equations do not accurately reflect the diversity of the current military populations. The services' populations are becoming more variable with respect to gender, age, and ethnicity. The increasingly diverse military population means that more women, who have a greater variety of body types for which the services' equations do not adjust, may not be treated fairly.

All branches of the military have established body composition standards for accession and retention. Failure to meet the weight-for-height standard results in the application of anthropometric assessment to determine percent body fat. The influx of women in the military pointed out that the universal application of body composition equations was not equitable. Since body composition standards are vital to military readiness, setting different standards for men and women is a sensitive topic. Gender-neutral fat standards set to a level that is appropriate for men are not appropriate for the health and fitness of women because women's gender-appropriate fat is in greater proportion to total weight and is distributed differently (Friedl, 1998). Biologically inappropriate fat standards for women will impair their military readiness, therefore gender-appropriate standards for body fat and or body weight, along with physical training programs, nutrition counseling, and fitness facilities will enhance readiness of all soldiers.

A comprehensive look at gender issues in the military fitness programs by the GAO indicates that DoD officials have begun to address some of the inequities in the services' fitness programs. There is agreement that there will be one body fat equation for men and one for women that will be in effect for all the services. Recommendations stated in the 1998 IOM report are being reviewed, and a draft of policy revisions is in progress. In addition, the Office of the Assistant Secretary for Force Management Policy requires from the services that they now must provide an annual report on the fitness programs, which should provide a good monitoring mechanism. The GAO report recommended that a mechanism be established for providing policy and research coordination among the services of physical fitness and body fat programs.

2.3.2 Ethnic Differences

Fat-free mass, total body fat, and fat distribution vary with ethnic makeup (IOM, 1998). These differences in body composition call into question the constant body density assumption used in common body composition assessment methods.

The most prominent contrast is that of FFM. From fetus to the tenth decade, African-Americans tend to have greater bone mass, bone diameter, and bone volume compared to Caucasians (Garn, 1992). Data also suggests that African Americans have slightly more muscle area (Tanner, 1964; Frisancho, 1990). African-Americans tend to be slightly taller than Caucasians starting in adolescence and African-Americans tend to have narrower waists and hips than whites, with broader shoulders, biceps, and forearms (Behnke & Wilmore 1974; Garn, 1992).

For women and men, there are considerable differences between Caucasian and other groups regarding body composition. African-American women show an increased density in FFM that implies a

heavier and denser skeletal mass. Gallagher et al. (1996b) show that the increase in bone mass observed among African-American women compared to Caucasian women is due to total body bone mineral mass and greater appendicular lengths, and has been observed across the entire adult lifespan. Schutte, Townsend, Hugg, Shoup, Malina, and Blomqvist indicate that African-American men have denser lean body mass than Caucasian men. Genetic factors are also known to influence total body fat as well as its distribution. Gasperino (1996) studied ethnic differences in percent body fat and fat distribution and concluded that African-American women had lower body fat percentages than Caucasian women. This finding was supported by the work of Aloia, Vaswani, Ma, and Flaster (1997) but was not supported by two other studies that found no difference (Gallagher et al. 1996; Ellis, Abrams, & Wong, 1997).

There is some disparity among other sets of studies as well. Adams-Campbell et al. (1990) report that the upper body fat of African-American women is greater than that of Caucasian women of similar BMI. The waist-hip ratio of African-American women is reportedly greater than that of Caucasian women in some studies (Croft et al., 1996; Gasperino, 1996). Conversely, Stevens and coworkers found waist-to-midarm circumference ratio to be lower in a group of African-American women compared to Caucasian women (N=242 and N=312). Lower levels of adipose tissue in the upper body were found for African-American women compared to Caucasian women (Conway, Yanovsky, Avila, & Hubbard, 1995), and lower levels of total, visceral, and subcutaneous adipose tissue were found for African-American women compared to same-weight Caucasian women. Albu, Murphy, Frager, Johnson, & Pi-Sunyer (1997) report lower visceral adipose tissue and visceral-subcutaneous adipose tissue ratios for a given waist-hip ratio (adjusted for total body fat) for 25 African-American women compared to 25 Caucasian women.

These results are not consistent with one another, probably due to methodological differences. While Thomas and coworkers (1997) found that African-American women had the smallest waist-hip ratio and the largest waist and gluteal circumferences among 143 women of four ethnic origins (Caucasian, African-American, Hispanic, and Native American), they also report that the variation within each ethnic group exceeded the variation between groups; they therefore concluded that it is not possible to predict a woman's ethnic origin based on body fat distribution.

The waist-hip ratio differences among ethnic groups are associated with differences in upper-body strength in women. Since all the services use circumferential methods of body fat prediction to determine accession and retention issues, controlling for ethnic differences in total bone density or regional body fat distribution is an important consideration (Garn, 1992).

2.3.3 Body Composition and Age

The Dietary Guidelines Committee (1995) does not liberalize the upper BMI as individuals age, even though there is agreement among investigators that body weight becomes more difficult to maintain with age. Williams (1997) argues that body weight and circumferences will increase with age unless there is a substantial increase in physical activity or a substantial decrease in caloric intake. Several studies indicate that this is the case for women (Forbes, 1987). The implication is that lean body mass decreases with age. This is also supported by Knapik et al. (1996) who showed that as men age, BMI increases while muscle mass and metabolic activity decrease. The Fels longitudinal study (Guo, Zeller, Chumlea, & Siervogel, 1999) shows an increase of body fat of about 0.37 kg/year and an increase in BMI of about 0.11 kg/m²/year for adults over 40 years of age. However, the increase in BMI can begin as early as in the mid-20's. None of the studies cited show that increased BMI and decreased FFM is causally related to aging, but rather only show associations. There is no proof that we must become fatter as we age.

Currently, the Army and the Air Force set body fat limits based on age, while the Navy and Marine Corps standards are age-independent. The Air Force allows 20% body fat for men 29 years old or younger and 24% for men 30 and older, while women 29 years or younger may have 28% body fat, and women 30 and older have a limit of 32% (AFI 40-502).

3. BODY COMPOSITION AND AIR FORCE FITNESS PROGRAM TIER I: HEALTH, WELLNESS, AND READINESS

The Air Force is currently working toward a two-tier approach to fitness. While the main thrust of this *Review & Analysis* is the relationship between performance of military tasks and body composition (Air Force Fitness Program Tier II—discussed further in following sections), it is important to present, as background and context, information about other military interests in body composition. This section includes information about Tier I of the Air Force Fitness Program and will take into account information regarding body composition standards as they apply to health, wellness, and readiness. For the sake of this discussion, “readiness” will be considered the general preparedness and fitness necessary for an individual to perform basic military tasks as determined by physical exercises such as push-ups, sit-ups, and running.

Each service is different in its fitness programs and body composition standards, although they have the same general goal—to produce a healthy, physically fit force ready for military service. At this time, none of the services has based its requirements on a specific job or combat mission. The differences among the services’ body composition standards can be accounted for in part by the different focuses of the services’ fitness programs. For example, the Navy sees health as the appropriate objective of its fitness program, and Navy standards reflect this emphasis. The Navy’s maximum body fat standard is 22% for men, which is the limit of clinical obesity according to the National Institutes of Health. The Navy reports, however, that this is clearly the upper limit and encourages personnel to strive for a lower body fat percentage. In contrast, the Marine Corps focuses on maximum physical fitness and has established 18% male body fat as its upper limit. Both the Army and the Marine Corps cite appearance as an objective of their fitness programs. Clearly there is some disparity in the goals of military fitness programs that are reflected in the services’ standards.

3.1 BODY COMPOSITION AND HEALTH AND WELLNESS

Body composition has been shown to have a dramatic impact on health and wellness. A high level of body fat is associated with increased probability of developing several diseases. However, not having enough body fat can affect an individual’s wellness, too. This section will discuss the benefits and drawbacks of moderate versus extreme body fat, respectively.

3.1.1 Health

While other factors are certainly crucial to maintaining good health, having a moderate and consistent level of body fat is also important. The IOM (1998) study reports that an increased percentage of body fat is associated with numerous health problems and a decrease in some measures of fitness. Obesity is associated with an increased risk for diabetes mellitus, heart disease, high blood pressure, osteoarthritis, and some cancers (Nieman, 1998). Those with excess accumulation of abdominal fat are at increased risk for a number of illnesses compared to individuals with fat stored in the lower extremities. However, it is important for military policy to note that the consensus among several studies of BMI and morbidity/mortality is that both high and low BMI negatively affect health.

The current, widely used Dietary Guidelines of the USDA (USDA, 1995) recommend a BMI range between 19-25 kg/m². Other federal agencies consider a BMI between 18 to 28 kg/m² as “healthy” (IOM, 1998). Manson et al. (1995) found that risk did not increase significantly until BMI reached 27. However, not all experimental work supports these ranges; a meta-analysis by Troiano, Frongillo, Sobal, and Levitsky (1996) indicates that weight levels considered to be moderately overweight are not associated with increased mortality. In addition, while some women with low BMI can be very physically fit (IOM, 1998), levels of 17 to 18.4 BMI have been associated with chronic energy deficiency (James, Fero-Luzzi, & Waterlow, 1988).

3.1.2 Injury

A series of studies by Jones and coworkers (1994, 1992) reports a weak association between BMI and exercise-related injuries. The relationship is portrayed as bimodal, with individuals with a very high or very low BMI being at greater injury risk, at least for men (Jones 1992). For women, risk was significantly increased only with low BMI, indicating that those with low body fat might not have sufficient fat-free mass to adequately support their weight. Kowal (1980) for example, showed that women's injuries during endurance training tended to be associated with higher weight and percent body fat. These characteristics might have been secondary to a lack of fitness.

3.2 BODY COMPOSITION AND READINESS

Military readiness can be defined as general preparedness to perform basic military tasks. It has several important components, whose relationship to measures of body composition are documented in this section. The term fitness is used here to cover standard physical fitness capacities and tests of these capacities. The relationships between body composition and running, sit-ups and push-ups, and strength measures are detailed here, and the appearance of fitness is also discussed.

3.2.1 Fitness

One of the most widely accepted definitions of physical fitness, by Bouchard and Shephard (1994), was devised for the International Consensus Conference on Physical Activity, Fitness, and Health. Their definition, that fitness is “the matching of the individual to his or her physical and social environment” (p. 81), goes on to point out that the goals of fitness are two-fold— health and performance, which lie on a continuum. Health-related fitness, according to Bouchard and Shephard, is characterized by “an ability to perform daily activities with vigor” (p. 81), and a low risk of developing several degenerative diseases. Components of health-related fitness are strength and endurance, body composition, intracellular metabolism, and cardiovascular and respiratory function. The components of performance-related fitness include muscular power, strength, and endurance; body size, body composition, motor skills; motivation; nutritional status; genetics; and cardiorespiratory capacity and power.

In the most general sense, how do body composition factors affect physical capacity? Astrand and Rodahl (1986) explain that greater stature is associated with longer muscle length which in turn is associated with greater muscle cross-sectional area and muscle mass, for two individuals of the same absolute muscularity. (Stature, by itself, does not dictate a greater cross-sectional area and mass, only a greater muscle length.) The muscle mass area and mass of the taller person is related to greater force development compared to that of a shorter person, with strength and aerobic capacity being proportional to the cube of height, and with aerobic capacity being proportional to two-thirds of body weight. Also evident are the relationships between exercise capacity and body composition. The body type of the typical marathon runner is lean and associated with modest muscle mass, whereas a defensive lineman will have a large muscle mass and modest-to-high levels of body fat (Vogel & Friedl, 1992).

Harman, Frykman, Lammi, & Palmer (1996) also document the theoretical basis for the belief that excess body fat is detrimental to certain types of performance. Fat tissue, whose main purpose is for energy storage, does not contract and therefore does not assist in force generation. However, fat tissue does have mass and weight, which means that muscles must produce more force in order to support the body segments against gravity and to overcome inertia during acceleration (Boileau & Lohman, 1997). Fat deposits thus increase the mass of the body and the weight and inertia of body segments. This becomes important when we consider endurance activities such as running. During locomotion, the body's center of mass rises repeatedly, and an increase in either the body weight or the vertical travel of the center of mass raises the power requirement.

Beyond this theoretical base, there is greater empirical evidence that fat weight diminishes performance on some physical fitness tasks. The upcoming sections describe studies that examine the

relationship between common physical fitness tests and body weight, BMI, and measures of body fat. Does performance on these tests of fitness bear a significant relationship with any measure of body composition? A later section of this *Review & Analysis* examines the relationship between body composition measures and performance of military tasks.

3.2.1.1 VO₂max Uptake and Running

Significant correlations have been found between measures of body fat and fitness. Vogel and Friedl (1992) found a correlation of -0.48 between percent body fat and mean oxygen uptake for men, while Jette, Sidney, and Lewis (1990) found correlations of -0.41 and -0.54 between BMI and maximum oxygen uptake (VO₂max) for women. The findings of Jones, Bovee, and Knapik (1992) showed correlations between percent body fat and 1 and 2-mile run times for men of 0.27 and 0.53 , and for women, 0.12 and 0.16 , which means that fatter men and women run more slowly than their trimmer counterparts. When comparing BMI to percent body fat as a measure, Jones et al. (1992) found a similar but less strong relationship between BMI and run times, compared to percent body fat. They state that this may be because BMI is a surrogate measure of percent body fat, with the inert fat tissue detracting from weight-bearing endurance performance.

Excess weight has been shown by several others to affect running performance, as indicated in work by Cureton et al. (1978) and Cureton and Sparling (1980). In both experiments, weights were added to the trunks of runners as a simulation of the effects of added fat weight. The added weight decreased VO₂max relative to body weight, but did not affect absolute VO₂max (l/min) or VO₂max relative to FFM. In terms of performance, in both studies, the added weight decreased endurance time on a treadmill, and shortened the maximal distance run. This work demonstrated a negative effect on running time that could be attributed to excess weight alone, with no change in cardiovascular capacity.

Table 3 from Harman and Frykman (1992) shows the negative relationship between percent body fat and running performance for several studies. The relationship is consistent in direction but is not strong.

Table 3. Running Performance Correlations with Percent Body Fat

Study	Task	Male R value	Female R value
Friedl (unpublished)	2 mile run	-0.36	-0.12
Knapik (unpublished)	2 mile run	-0.38	
Mello, Murphy & Vogel (1984)	2 mile run	-0.60	-0.35
Harman, Sharp, Manikowski, Frykman, & Rosenstein. (1988)	2 mile run	-0.46	
Myer, Gebhardt, Crump, & Fleishman (1983)	2 mile run	-0.21	-0.19
Cureton, Hensley, & Tiburzi (1979)	12 minute run	-0.30	-0.22
Fitzgerald et al. (1986)	2 mile run	-0.47	-0.31

(adapted from Harman and Frykman, 1992)

3.2.1.2 Sit-ups and Push-ups

Fitness strength tests often include sit-ups and push-ups. It is important to note that sit-ups and push-ups differ from other measures of strength and endurance in an important way—they require lifting of the body while other measures assess strength irrespective of body weight.

Vogel and Friedl (1992) found that excess weight diminished performance of sit-ups and push-ups. Supporting this finding is work by Jette et al. (1990b), showing that higher BMI was associated with

lower sit-up scores ($r=-0.24$ and -0.15 for men and women respectively) and lower push-up scores ($r=-0.22$ for both men and women).

A study by Westphal et al. (1995) examined body composition variables such as weight-for-height, BMI, total body fat (using all services' circumference equations), total body fat from DXA, and body fat calculated from the waist-hip ratio. The corresponding performance variables were Army PFT performance scores, and scores on a torque task, machine lift, bench press, military press, and vertical jump. Westphal and coworkers' results showed that increased BMI showed no association with pushups, but was associated with decreased sit-up performance. A waist-hip ratio greater than 0.81 was associated with poorer sit-up and push-up performance.

Jones et al. (1992) gathered data in 1984 and 1988 on more than 2000 Army trainees entering Fort Jackson. Prescreening measures included height, weight, percent body fat, body mass index, and Army physical fitness test results. They found that men entering the Army with lower body fat percentages tended to be able to perform more sit-ups and push-ups. For women, the relationship between body fat and fitness task performance was not as clear.

3.2.1.3 Other Measures of Strength

The study by Westphal et al. (1995, described above) showed that increased BMI was associated with increased performance on strength tasks (military and bench presses, a torque task and grip strength). A waist-hip ratio greater than 0.81 was associated with increased torque task performance. In addition, in the Jette et al. (1990b) study, higher BMI was associated with greater grip strength.

Several studies bear out this conclusion. Body weight was significantly positively correlated with Incremental Lift Machine (ILM) scores and box-lifting task scores for both men and women (Stevenson, Greenhorn, Bryant, Deakin, & Smith, 1996); similar findings were reported by McDaniel, Kendis, and Madole (1983) who reported correlations of 0.36 and 0.49 for females and males respectively for weightlifting capability and body weight (Stevenson et al., 1996).

Further evidence is provided by Sharp (1994), who found that women who exceeded the Army's weight-for-height standard during Army basic training performed better on strength tasks than those within the standard range; those same women who exceeded the body fat limit did perform better on strength tasks, but the difference was not as great when the measure was BMI. That is, the weight-for-height standard eliminates more strong women than the body fat index.

It is accepted that increased body fat is associated with decreased weight-bearing endurance performance, while increased lean mass which is often associated with greater body weight and body fat, is associated with greater strength (IOM, 1992) and increased lifting ability.

The data presented in this section and previous sections lead to the conclusion that increased body fat negatively affects push-up and sit-up performance as well as weight-bearing endurance tasks, such as running. With push-ups and sit-ups, a portion of body weight has to be lifted against gravity, and running requires that the entire body weight, including fat, must be lifted (IOM, 1992, p. 165). However, higher BMI is often associated with greater strength, which may account for the increased performance on strength tasks that do not involve lifting body weight (military press, bench press, grip strength, and torque).

Studies supporting the relationship between increased fat-free mass and strength tasks are presented in the section titled, *Air Force Fitness Program Tier II*.

3.2.2 Military Appearance

The 1998 National Academy of Science report and their earlier 1992 report points out that the "appearance" rationale for body composition standards does not have a substantial relationship to performance, fitness, nutrition, or health (IOM, 1998). However, officials from two services, the Army and the Marines, told GAO staff that appearance was one objective of their fitness programs, stating that image is an important component of effectiveness. Since the image of a soldier is one of leanness, a fat

appearance could weaken the military image and undermine effectiveness and thus, readiness. The Navy reports that appearance is not an appropriate objective of their body fat program, but in fact, Navy body fat results are incorporated into an individual's rating in the "military bearing" category of officer fitness reports and enlisted personnel evaluations.

Several studies throughout the years have sought to establish the relationship between what is accepted as military appearance and veridical measures of body composition of height and weight. A brief history of the relationship between visually judged military appearance and actual body composition includes the work of Dupertuis (1950) who found a correlation of -0.85 between endomorphy ratings and body specific gravity. In 1952, Brozek and Keys found a mean correlation of 0.67 when subjects were rated before and after a period of semi-starvation. Ward, Sutherland and Blanchard (1976) found reliable responses of body fatness by visual appraisal, as did Blanchard, Ward, Kryzwicki, and Cannam (1979). Sterner (1984) used photographs and two raters to estimate fatness. Correlations between percent fat as documented by hydrodensitometry and that predicted from visual estimation were 0.80 and 0.79 for the two rates. Test-retest correlations were 0.93 and 0.95 for the two raters.

Subsequent to this work, Hodgdon, Fitzgerald, and Vogel (1990) conducted an experiment to determine how strongly ratings of military appearance and fatness were associated, and to consider how reliable and valid assessments of fatness can be made in a military population that includes personnel of both genders, and various ages and races. Subjects were 1326 US Army active duty personnel, including men and women, whose body composition was established by hydrodensitometry. Appearance and fatness were rated by 11 personnel, male and female, officer and enlisted, and African-American and Caucasian. Fatness was rated on a scale from 1 (very thin) to 7 (obese) by viewing swimsuit photographs. Military appearance, using Class A uniform and swimsuit photographs, was rated on a scale of 1 (poor) to 5 (excellent). Raters were asked to use their own personal standards to assess "military appearance." Hodgdon et al. (1990) found that while fatness ratings could be considered valid and reliable, ratings of appearance did not fare as well. Ratings of appearance in uniform were not highly correlated with percent body fat (0.53 for males and 0.46 for females). The authors conclude that factors other than body composition, such as subjective judgement, may influence ratings and that, "...it is not feasible to establish a single rating procedure which can be used to rate both military appearance and fatness" (p. 22).

4. BODY COMPOSITION AND AIR FORCE FITNESS PROGRAM TIER II: JOB-SPECIFIC STANDARDS

Interest in determining job-specific fitness standards, of which body composition is a subset, dates back to at least 1713 (Shephard, 1990, citing Bernardino Ramazzini) with a mocking description of sedentary and unfit guild workers. Early industrial work in body composition standards took place in the 1950s (Gilson and High-Jones, 1955; Shephard, 1957). While all military branches use some form of physical fitness and body composition testing, no military occupations require a specific body composition standard.

4.1 HISTORY AND CURRENT STATUS OF MILITARY BODY COMPOSITION STANDARDS

Job-specific performance in the military has been a concern since the Army Air Corps Aviation Psychology Program began in World War II (Hogan, 1991). Over the last three decades, interest in job-specific performance testing has increased with the dramatic influx of women into the military services as well as into demanding MOSs. In the 1970s, the US Army Research Institute of Environmental Medicine (USARIEM) was tasked with developing performance tests to match the soldier to the Military Occupational Specialties, but these tests were never fielded. Subsequent efforts included USARIEM's development of MEPSCAT, a gender-neutral military entrance strength capacity test (IOM, 1998).

With increasing numbers of women entering the military services, in 1976, the Government Accounting Office (GAO) encouraged the Department of Defense to develop physical standards for job performance using the Department of Labor system of classification (GAO, 1976, as cited in IOM, 1998). Since then, each service has categorized its occupational specialties according to upper body strength, and the P-U-L-H-E-S physical profile serial (physical capacity or stamina, use of upper and lower extremities, hearing acuity, normal color vision, and special psychiatric characteristics). Incoming personnel would then be required to meet the criteria to enter a specific occupational specialty and maintain that fitness level to perform the specified tasks.

In 1993, legislation that opened all MOSs to women (except direct combat) led to the GAO being directed to re-open the issues of job-specific performance testing. The GAO recommended that the services determine whether a significant problem existed in the accomplishment of physically demanding occupations, and to identify ways to solve the problem. The GAO report (1996) recommended establishing valid performance standards, providing job training, and redesigning job tasks. Only the Air Force requires recruits to take a strength test for MOS assignment at accession (IOM, 1998).

Presently, the Air Force AFSCs are categorized into eight physical demand categories, and the USAF uses a strength aptitude test to screen out those recruits who would not be likely to perform successfully on a given job (AFMAN 36-2108, 1998). The Air Force does not incorporate this strength test into the required annual fitness evaluation. The Navy has not adopted occupational strength standards for active duty personnel or recruits. The Marine Corps at one time administered a physical readiness test of combat skills, but this has been discontinued. The Army categorized all its enlisted occupational specialties into five categories based on physical demand, but ceased testing recruits' physical capabilities to perform specific jobs in 1990. Until that time, test results were used only to counsel recruits about entering a specific occupation (GAO, 1996).

The GAO Guidelines (1998a) report indicates that Section 543 of the 1994 National Defense Authorization Act "required the Secretary of Defense to prescribe physical performance standards for any occupation in which the Secretary determined that strength, endurance, and cardiovascular capacity was essential to the performance of duties" (p. 8). This act requires that, if developed, these standards will pertain to job activities that were commonly performed in that occupation, and must be relevant to successful physical performance of those tasks, and could not be based on gender. "In other words, job-specific physical performance standards would identify the absolute minimum level needed for successful performance in those occupations. Anyone in that occupation, regardless of gender, would be required to

meet the same standard” (p. 8). An example of a job-specific fitness program is the recently-restructured training and testing program that the Air Force conducts for all military firefighters (Palmer, Carroll, & Mirza, 1998).

Several researchers and government documents report that developing occupation-specific fitness standards, including body composition standards, would be desirable, as can be seen in Table 4.

Table 4. Subject Matter Experts' Comments on Occupation-Specific Standards

The Committee on Body Composition, Nutrition, and Health of Military Women (IOM, 1998, p. 160)	“The committee further recommends the development of task-specific, gender-neutral strength and endurance tests and standards for use in the determination of placement in military occupational specialties that require moderate and heavy lifting. . . .The BCNH committee recommends that, in view of the association between FFM (as an indicator of skeletal muscle mass) and strength, that the military consider developing an appropriate minimum recommended BMI for accession of women.”
Smith (1998, p. 246)	“The Army Body Composition Program should be discontinued. . . . Research concerning body composition, nutrition, and physical training should focus on identifying valid performance criteria for selecting and training soldiers.”
Harman and Frykman (1992, p. 117)	“The US Army should clearly define its reasons for having body composition standards. This report has shown that existing standards are not well related to military task performance.”
Vogel and Friedl (1992, p. 100)	“These relationships are important. . . (1) to set body composition standards that will support the level of physical performance capacity that is required and (2) to appropriately express fitness capacity tailored to different occupational activities.”
Hodgdon (1992, p. 59)	“The possibility exists for using FFM as an approximation of overall strength in job assignment.”
The Committee on Military Nutrition Research (IOM, 1992, p. 26)	“A body composition standard in the military should be based primarily on ability to perform required physical tasks and secondarily on long-term health implications. A stronger rationale needs to be developed for basing the standard. The conclusion relates only to service-wide standards, not the more stringent standards required for particular military occupation specialties.”

The opinions of these experts favor job-specific fitness standards, with some experts recommending job-specific body composition standards. If Air Force policy follows this recommendation, the next step will be to agree on what measure of body composition best predicts military task performance.

4.2 WHAT PARAMETER OF BODY COMPOSITION SHOULD BE USED?

The thrust of the Air Force Fitness Program’s Tier Two is to establish standards that are specific to job performance. While it is often assumed that performance on physical fitness tests predict performance on the job, this is not borne out by empirical findings. “Unfortunately, performance on the standard physical training (PT) test does not correlate well with measures of military performance, because there is little need for unloaded running, sit-ups, or push-ups in normal daily military activity. Although

overweight individuals perform relatively poorly while underweight individuals perform relatively well on PT tests, the usefulness of these measures as a predictor of military performance is limited” (IOM, 1992, p. 13).

Lifting and carrying are common, physically demanding tasks in the military. They differ from one another in that in carrying tasks, involves moving the body mass as well as the object, whereas body mass is less a part of a lifting task (Hodgdon, 1990). This section describes several research studies that examined the relationship between body composition variables and military task performance.

4.2.1 Fat-Free Mass and Military Tasks

Military tasks that are physically demanding involve such activities as loading artillery shells, lifting supplies, unloading aircraft and trucks, and assembling and disassembling equipment (IOM, 1992). Harman and Frykman (1992) indicate that the most common physically demanding Army tasks are lifting and carrying, with most lifts involving raising an object from the ground to between waist and shoulder height. Usually a single soldier is expected to lift up to 50kg, often with no handle. In heavy lifting jobs, between 85 and 200 pounds may be lifted by one person, and may be carried up to 200 yards (Myers et al. 1983; US Army, 1978). A pack weighing more than 100 pounds may be carried for several miles. Although running is part of the Army PRT, Harman and Frykman note that “...there is little evidence that unloaded running ability relates to military performance. Running more than a mile without a load is a task rarely demanded of a soldier” (Harman & Frykman, 1992, p. 108).

Beckett and Hodgdon (1987) assessed the relationship between body composition and other fitness measures and three tasks representative of general shipboard work. Performance was assessed on the Navy’s Physical Readiness Test (PRT), other field fitness measures, and an Incremental Lift Machine test, for 102 Navy men and women. (The Navy’s PRT consists of sit-and-reach distance, time for a 1.5 mile run, number of sit-ups that can be performed in 2 minutes, and the number of pushups that can be performed in 2 minutes.)

The three shipboard tasks were a long-duration carry task and two maximal box lifting tests. The long-duration carry task involved making as many round trips as possible on a 51.4 m course in two 5-minute bouts, carrying a 34 kg small metal box. There was a 1-minute rest between bouts. The two lifting tasks involved lifting a metal box from deck to elbow height and then from deck to knuckle height. Weight was successively loaded after each successful lift so that capacities for lifting to elbow and then knuckle height could be determined.

The following table (Hodgdon, 1990, describing the 1987 Beckett and Hodgdon work) details correlations for the Navy PRT items and body composition variables with performance on the materials handling tasks. Clearly, fat free mass was the best predictor of all for the box lift tasks, and was second only to number of pushups in being a positive predictor of box carry power. Run time had a greater negative relationship with box carry power. Neither percent fat (from circumference measures) nor fat mass was a good predictor for either task.

Table 5. Correlations among Navy PRT Items and Body Composition Measures with Materials Handling Tasks

Fitness Variable	Box Lift Maximum Wt	Box Carry Power
Sit-Reach distance	-0.21	0.01
Situps in 2 minutes	-0.00	0.31
Pushups in 2 minutes	0.63	0.56
1.5 mile run time	-0.34	-0.67
Percent fat	-0.36	-0.43
Fat-free mass	0.84	0.44
Fat mass	0.08	-0.23

From Hodgdon, 1990

Hodgdon (1990, discussing the 1987 work) concludes, “These [body fat] correlations suggest that using relationships between these tasks and percent fat as the basis of setting percent fat standards would not be particularly fruitful. However, it might be noted that one of the body composition variables (fat-free mass) is highly correlated with box lift maximum weight. In this study, fat-free mass was found to be highly correlated with other muscle strength measures. The possibility exists for using fat-free mass as an approximation of overall strength in job assignment” (p. 2).

Earlier, similar work by Robertson and Trent (1985) and Marcinik, Hodgdon, Englund, and O’Brien (1987) employed tasks of short duration only, including a barbell lift to a rack, and a canopy-raising simulation. Robertson and Trent assessed the relationship between task performance and performance on a battery of anthropometric, strength, power, and calisthenic measures. Shipboard task performance was most highly correlated with arm power, static upper body strength, and body weight. Incremental lift and lean body mass also significantly correlated with task performance. Marcinik et al. (1987) examined the relationship between five simulated shipboard tasks, the PRT, and the Incremental Lift Test. Lift test and lean body mass were the best correlates of task performance.

Supporting the relationship between fat-free mass and military task performance is work by Knapik et al. (1990). To determine the relationship between soldier load carriage performance and several physiological and psychological measures, Knapik et al. monitored load carriage performance (carrying 46 kg over a 20 km distance as fast as possible) for 93 male Army soldiers. Although a variety of factors were of interest in this study, one finding relevant to this *Review & Analysis* was that higher fat free mass was associated with faster road march time. The findings document how fat free mass is important for load carriage; the person with more fat free mass will carry less load per unit of fat free mass since the load is distributed over a larger amount of tissue.

Furthermore, Sharp et al. (1994) found that women recruits who failed the weight-for-height standard performed better on measures of lifting and carrying than those who were within the standard. This same effect was found for the body fat standard, although it was less pronounced. The relationship between increased waist-hip ratio and torque test performance established by Westphal et al. (1995) adds to the implication that increased weight-for-height and increased waist-hip ratios are associated with higher FFM and greater strength.

The relationship among body composition variables and performance is complex, but it appears that for both sexes, those who exceed weight-for-height or body fat standards perform better on strength tasks and worse on aerobic tasks. This is probably due to the larger FFM that may accompany increased weight and fatness. Body fat alone is not a sufficient index of physical ability. This finding is supported by the 1998 IOM study:

“Some research has found that the higher the percentage of body fat the lower the performance in running tests. However, research also shows

that women recruits who failed body fat standards were stronger than their counterparts who passed. The situation presents a dilemma for the military; setting a high body fat limit favors selection of women who are strong but may lack optimum endurance, and vice versa. The Academy's report pointed out that, to some degree, current body fat standards may discriminate against women who would be the most capable of performing jobs requiring strength, which might be the most critical for survival in a combat situation" (IOM, 1998, p. 9).

It appears that there is considerable documentation that fat-free mass is a better predictor of performance on military tasks than percent body fat. Following are several quotations from major studies and researchers regarding the use of lean body mass or fat free mass as the parameter most useful in predicting performance on military tasks.

Table 6. Fat-free Mass is Recommended as a Military Body Composition Parameter

BCNH (IOM, 1998,p. 160)	"The BCNH committee recommends that, in view of the association between FFM (as an indirect indicator of skeletal muscle mass) and strength, the military consider developing an appropriate minimum recommended BMI for accession of women."
Westphal et al., (1995, p. 133)	"Higher body weight and fat-free mass were correlated with greater muscular strength, a desirable trait in many military occupational specialties. This reaffirms the need to balance current body composition standards against strength requirements, perhaps with the eventual inclusion of minimum lean mass standards."
CMNR (IOM, 1992, p. 26)	"In view of the positive relationship between fat-free or lean body mass and physical performance, the military should seriously consider establishing a minimum standard for lean body (that is, fat free mass) mass. There is doubt among the members of the CMNR as to whether the military should continue to employ a maximal body fat standard."
Hodgdon (1990, p. 1)	"Our investigation of relationships between body composition variables and performance of materials handling tasks suggest that percent fat is not strongly related to performance. Estimated fat-free mass , on the other hand, is highly correlated with strength and ability to lift objects."
Mello, Nindl, Sharp, Rice, Bills, Patton (1995, abstract)	"Alternate variables such as total and regional FFM and anaerobic power need to be examined as preplacement measures."

However, it should be noted that percent body fat is the appropriate measure for health-based standards. Chumlea and Baumgartner (IOM, 1992, p. 179) state that "there is little or no information that associates FFM with disease or death except for the changes that occur during weight loss or in association with eating disorders."

4.3 HOW CAN WE ESTABLISH A STANDARD?

If the Air Force enacts policy to investigate the possibility of job-specific body composition standards, a definitive analysis of representative military tasks must be conducted. The process of

undertaking a job analysis, establishing underlying physical characteristics, determining validity, and creating cut-off scores is described thoroughly by Jackson (1994) and Hogan (1991). There is considerable literature on task analysis within a military context; analyses of military tasks have been performed by several researchers, for all the services, over the past four decades (Vogel, Wright, Patton, & Dawson, 1980; Arbeit & Scheafer, 1977; Bellows, Browne, Germain, & Nichols, 1951; Myers, Gebhardt, & Fleishman, 1980; Koym, 1975). The procedures for performing a job analysis are well documented and the expertise is available to the military services fitness programs. In general, to perform a finer analysis of job requirements, one will follow the steps outlined by Shephard (1990). Shephard reviews the difficulties with current tests and standards for occupational fitness, and suggests these steps as an outline of how to establish work-related fitness standards. Body composition standards would be considered a subset of such an effort, along with strength and aerobic measures.

- The limiting steps in the work task must be defined by careful on-site observations and discussions with a representative group of supervisors and workers.
- The frequency of occurrence of individual limiting steps in an industrial process must be established. It must further be confirmed that the items identified are vital to the safety and efficiency of work performance, and cannot readily be eliminated by an alteration of job design.
- A discriminant analysis must next relate the performance of potential test items to success or failure on the job.
- A composite score will ultimately be derived from three or four of the most promising tests. If these are relatively independent of each other, and have an individual test/retest reliability of 95% or better, the lack of reliability for the composite score will be $5\%/\sqrt{n}$, or about 2.5%. Then, as for other diagnostic procedures, the sensitivity and specificity of the index must be optimized. If public safety is the issue, the choice of limiting score may be biased toward sensitivity (that is, with a minimum acceptance of unqualified workers), but if the concern is an unwarranted exclusion of capable workers, then the minimum standard of performance may be tipped in favour of specificity (that is, with a minimum rejection of workers able to carry out the required job). (p. 94)

4.3.1 Grouping Air Force Specialty Codes

The studies in the previous section of this *Review & Analysis* indicate that, of all the possible relationships between the different measures of body composition and the performance of military tasks, the one relationship that is most clear is the positive correlation between fat-free mass and lifting and carrying tasks. If the goal of the Air Force Fitness Program is to establish a body composition standard that has a valid relationship to the accomplishment of military tasks, it is then logical to categorize the Air Force Specialty Codes (AFSCs) according to weights commonly lifted or carried. To deal with this on a conceptual level, a notional approach would be to group AFSCs into four categories—jobs with truly minimal physical demands (Group 1, whose standard will be the military health-based standard of Tier 1), jobs with some light lifting or carrying (Group 2), jobs that require substantial lifting and carrying (Group 3) and special operations positions that require rigorous work under difficult conditions (Group 4). For each of several fitness capacities, (e.g. cardiovascular; muscle strength, muscle endurance, and flexibility, and body composition), there will be four sets of standards, representing the SC Groups. Scores are arbitrary for use in this example. Table 7 illustrates notional standards for fat-free mass for both tiers that will be used by the Air Force.

Table 7. Air Force Notional Fat Free Mass Requirement

AFSC Groupings	Physical Demand	Tier 1 Minimum FFM	Tier 2 Minimum FFM
Group 1	Minimal	X = minimum level	X = minimum level
Group 2	Light lifting/carrying	X = minimum level	X = minimum level + a%
Group 3	Substantial lifting/carrying	X = minimum level	X = minimum level + b%
Group 4	Rigorous work/Difficult conditions	X = minimum level	X = minimum level + c%
		Gender Differences	No Gender Differences

Currently, all of the services sort their jobs by lifting categories to some degree. The lifting categories for each of the three services are broken down in Table 8:

Table 8. Military Lifting Categories--Triservice Survey

Lifting Parameters		Army Category	Navy Category	Air Force Category
Occasional	Over 100 lbs	Very Heavy	High/High	High
Frequent	Over 50 lbs			
Occasional	100 lbs	Heavy	High/Moderate	
Frequent	50 lbs			
Occasional	80 lbs	Moderate/Heavy	Moderate/Moderate	
Frequent	40 lbs			
Occasional	50 lbs	Medium	Moderate/Low	Moderate
Frequent	25 lbs			
Occasional	20 lbs	Light	Low, Moderate and Low, Low	Low
Frequent	10 lbs			

(adapted from IOM, 1998)

Three Air Force categories are compared here, but there are eight strength categories used to rate AFSCs. Currently, the Air Force uses strength aptitude codes G-P derived from the SAT (Strength Aptitude Test) to determine a soldier's eligibility for a given AFSC. Failure to meet a given standard precludes an individual from performing a job with that code or higher. For instance, if a person can not lift 90 lbs overhead head, that person would be ineligible to perform duties with a AFSC of N or higher. Table 9 outlines these codes and the lifting capacity necessary to qualify (AFMAN 36-2108).

Table 9. Strength Aptitude Codes for AFSC Entry

Code	Demonstrated by Weight Lift of
B	Unknown
F	Less than 40 lbs
G	40 lbs
H	50 lbs
J	60 lbs
K	70 lbs
L	80 lbs
M	90 lbs
N	100 lbs
P	110 lbs

4.3.2 Establishing a Standard for Fat-Free Mass for Each Set of AFSCs

So far in this section of the *Review & Analysis* it has been established that there is some opinion that the military services would benefit from a set of body composition standards that are job-specific. There is sufficient evidence that fat-free mass or lean body mass correlates better than any other measure with performance of military tasks such as carrying and lifting. Running performance has been shown to have a negative correlation with body fat ($r = -.21$ to $-.60$) as well as lifting ability. The less overall mass an individual has, the easier it is to perform in tasks dependent on body weight, including running tasks. This includes FFM. However, lifting performance suffers with a decline in FFM and overall body mass (Harman & Frykman, 1992). In light of these results, the current cardiovascular testing performed by the Air Force Fitness Program can still be seen as a valid assessment of that capability at least for health and fitness purposes. The task that remains is to match levels of fat free mass with the four notional categories of AFSCs illustrated earlier, or some other possible breakdown.

4.3.2.1 Predicting Performance on a Military Task from a Test Score

It would be necessary as a next step to quantify the relationship between performance on a military task and some underlying physical capability, as indexed by a test score. An example comes from the work of Sharp, Rice, Nindl, Mello, and Bills (1998), who were able to significantly predict performance ($R^2 = 0.69$) on a gender-free team lifting and carrying (L & C) task for pre-placement screening purposes. By assessing only three measures for the two individuals; sum of team height (sHT), sum of team bench press (sBP), and the sum of the maximum amount each person could lift and carry in a box one time (sIND 1RM L&C), Sharp et al. were able to account for over two-thirds of lift and carry task performance using this prediction equation:

$$\text{Load (kg)} = -71.142 + \text{sHT}(0.299) + \text{sBP}(0.422) - \text{sIND 1RM L\&C}(0.257)$$

Standard error of estimate = 8.57 kg

This equation and similar ones have great value in both military and civilian personnel screening. The ability to predict performance at a low cost from simple measurements could have a significant impact on selection. While these studies provide a direct measurement and predictor of performance, taking us one step closer to developing a scientifically-based predictor of performance, further studies similar to this will help the Air Force determine valid standards for categories of jobs.

4.3.2.2 Predicting ILM Performance from Fat-Free Mass

Once a relationship similar to the one above has been established, it remains to document the tie between a measure of body composition and a score on the test that measures the relevant capability. Hodgdon and Beckett (1987) supplied data that mathematically shows a direct linear relationship between FFM and performance on military lifting tasks ($R=.833$). In this case an incremental lifting task (ILM) was performed. Work by Hodgdon and coworkers performed with 101 active-duty Navy personnel showed that this relationship can be expressed in a prediction equation (Hodgdon, personal communication, May 17, 1999):

$$\text{ILM} = 1.342 \times \text{FFM} - 28.595$$

$$\text{Standard error estimate} = 8.503 \text{ kg}$$

$$\text{Standard error of measurement} = 8.461 \text{ kg}$$

For example, an individual who weighs 85 kg and has 20% body fat has 68 kg of fat free mass.

Therefore:

$$\text{ILM} = 1.342 \times 68 \text{ kg} - 28.595 = 62.661 \text{ kg}$$

Using the prediction equation, we can project that this individual can lift a maximum 62.661 kg while performing the ILM. Consequently, we can reasonably project the maximum lifting capacity for any soldier, given FFM and fat mass. This quantitative explication of the relationship between FFM and a measure of lifting capability is a good first step in determining necessary FFM values to accomplish a given set of tasks.

To establish job-specific body composition standards, AFSCs should be grouped according to their physical demands, in this case, lifting and carrying. The lifting and carrying requirements will then need to be matched with scores on a test that measures the underlying capability necessary to perform these tasks, such as the Incremental Lift Machine or the Strength Aptitude Test. The predictive equation between the strength test and a fat-free mass value will then need to be established in order for a minimum standard to be assigned to each group of AFSCs.

5. SUMMARY/CONCLUSIONS/RECOMMENDATIONS

5.1 SUMMARY

This *Review & Analysis* provides an outline of the Air Force Fitness Program as it exists today, as well as major initiatives in body composition and the history and drivers of DoD body composition guidance and military programs. Additional background information includes concepts and definitions of important terms, such as body mass index and fat free mass. The various methods of measuring body fat and FFM are then described. Further information explores the various factors that affect body composition, including gender, age, and ethnicity. Completing the background information is a summary of the major factors that military decision-makers may consider in addition to performance, including health, fitness, risk of injury, and appearance. This *Review & Analysis* then proceeds to explore the evidence in the literature in support of job-specific body composition standards. The *Review & Analysis* discusses which body composition parameter should be used, followed by a description of a process that could be used to match each AFSC with a standard.

5.2 CONCLUSIONS

The most direct measure of body composition that predicts military task performance is FFM. Common military tasks were considered to be lifting and carrying. The clearest finding in the literature was that greater FFM was associated with superior lifting performance. Therefore, if the Air Force desires a body composition measure that would have the greatest impact on military task performance, FFM would appear to be the measure with the best predictability.

5.3 RECOMMENDATION

If there is consensus among subject-matter experts and policy makers at the August *Health and Job-Specific Body Composition Standards Workshop* that the Air Force should adopt a process for establishing job-specific body composition standards, and if that consensus endorses the use of FFM as a predictor of lift task performance, then two tasks remain:

- To categorize AFSCs according to lift/strength requirements
- To quantify the relationship between lift requirements of job categories and FFM

How can we categorize Air Force Specialty Codes according to lifting and strength requirements? The *Review & Analysis* described a notional categorization of AFSCs as a starting point for this process. Actual lifting requirements could be mapped onto the notional plot, using the eight strength AFSC categories. To get an accurate and quantitative schema requires detailed job analyses. The standards and processes to do this are well documented.

A quantitative approach that would match the actual FFM to a lifting requirement is shown in the prediction equations developed by Sharp et al. (1998) and Hodgdon (personal communication, May 17, 1999) which predict military task performance from ILM score, and ILM score from FFM. Further studies on fat free mass as it impacts various tasks, is recommended. Air Force Specialty Codes can then be categorized using the four-group criteria, or some other approach. By using the physical measurements established by further study and the various AFSC categories, valid physical standards can be determined.

5.4 WORKSHOP AGENDA

The input of the subject-matter experts at the August *Health and Job-Specific Body Composition Standards Workshop* will be invaluable. The most important issue to be discussed will be the practical utility of establishing body composition standards that are specific to AFSCs. In addition, it is expected that the subject-matter experts will discuss these issues:

- Will there be significant savings in job efficiency, military readiness, injury reduction, and staff morale?
- Will these benefits outweigh the costs of the process to establish standards?
- Can the Air Force afford to be more selective rather than less selective in its recruiting and job assignment processes?
- Is the Air Force willing to deal with the effects of disgruntled personnel who do not conform to occupation-specific body composition standards but may otherwise be well qualified for a given assignment?

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7. APPENDIX A: METHODOLOGY

7.1 SEARCH METHODOLOGY

Information for this *Review & Analysis* was gathered from several sources. The bulk of information was derived from published literature, including journals, books, and technical reports from the fields of fitness, physiology, and others. Relevant literature was identified subsequent to a comprehensive computerized search of the literature. Literature searches were performed on several databases, including:

Aerospace Database
Books In Print®
Compendex®
Dissertation Abstracts Online
DTIC DROLS
PsycINFO®
National Technical Information Service (NTIS)
LCMARC-Books
SPORTDiscuss

Relevant and recent literature and researchers were identified and this information was used to access other sources. In addition to databases of literature, additional information was obtained from subject matter experts, personal communications, and electronic documents.

7.2 POINTS OF CONTACT/SUBJECT MATTER EXPERTS

Several military and civilian exercise physiologists and research scientists were interviewed for this *Review & Analysis* and provided valuable context and background information. An important phase of this project will be the *Health and Job-Specific Body Composition Standards Workshop* to be held on August 24, 1999, during which a consensus will be achieved among leading military exercise physiologists regarding job-specific body composition standards.

7.3 ORGANIZATION OF REVIEW & ANALYSIS

The first section of this *Review & Analysis* examines the Air Force Fitness Program, major body composition programs, and history of DoD body composition guidance. The history and current status of military body composition programs is then discussed. Background on concepts and definitions, factors affecting body composition, and additional considerations for measuring body composition are examined.

Specific standards of occupational physiology and job-specific standards are evaluated, including whether there should be job-specific body composition standards, which parameters should be used, and how AFSCs could be grouped. The results of all previous sections are synthesized and recommendations for action are made.